DEVELOPMENT OF A FIELD GUIDE FOR MINERAL DETECTION USING A PORTABLE SPECTROMETER IN THE TIR DOMAIN

W.Heldens[1], C. Fischer[2]

[1]Department of Remote Sensing, University of Würzburg, Am Hubland, 970704, Würzburg, Germany. wieke.heldens@dlr.de
[2]German Aerospace Center, German Remote Sensing Data Center, Department of Environment and Security, Münchener Straße 20, 82234, Oberpfaffenhofen, Germany. c.fischer@dlr.de

ABSTRACT:
Thermal spectral libraries are needed as reference for airborne hyperspectral imagery. In this study preparatory measurements have been taken with the portable Fourier transform infrared spectrometer (µFTIR) of Design & Prototypes with the aim to prepare a field guide on how to take reliable measurements in the thermal infrared domain. In this paper several influences on thermal field spectroscopy measurements are described. The emissivity of a set of well known minerals was measured with the µFTIR. The minerals were pre-processed using the µFTIR-software. Finding the right Planck curve for the emissivity calculation is important. An improved methodology is needed for that. Additionally the surface texture of the sample and the sample geometry (sun-sensor angle) should be taken into account.

KEYWORDS: thermal infrared spectroscopy, field measurements, µFTIR

1. INTRODUCTION

Thermal spectroscopy gains more and more interest in the hyperspectral remote sensing community. A broad thermal band provides information on the surface temperature, but many small bands in the thermal range revile spectral features determined by the chemical composition of the surface. Several airborne thermal hyperspectral sensors are already available (e.g: AisaOWL, TASI) to make use of this. To be able to work with the thermal hyperspectral image data, reliable spectral libraries of the thermal range are necessary. Different spectral libraries based on laboratory measurements already exist, but field measurements often still lack standard routines (e.g. Milton *et al. in press*).
Therefore, various aspects have to be taken into account when taking thermal field measurements. This work aims to describe the influences on field measurements in order to set up a systematic measurement procedure for a portable spectrometer.

2. METHODOLOGY

2.1. Emissivity

Emissivity is defined as the radiance of the object divided by the radiance of a black body of the same temperature as the object (thus, divided by the Planck curve). Radiance varies with temperature of the object while emissivity does not. Therefore emissivity is suitable for comparing spectra recorded at different times and places, analogue to reflection (which is the radiance of the sample divided by the radiance of a white standard) in the optical part of the spectrum.

In several existing thermal spectral libraries and in many laboratory studies hemispherical reflectance is measured (e.g. Salisbury & D'Aria, 1992). With Kirchoff's law this can be converted into emissivity and used for comparison.

Figure 1: µFTIR thermal field spectrometer of D&P

2.1 µFTIR spectrometer

In this study the portable Fourier transform infrared spectrometer (µFTIR) of Design & Prototypes (Korb *et al.* 1996) was used. This is a portable field spectrometer (see figure 1). An interferometer is used to measure the radiance at wavelengths between 2 and 16 µm. To calibrate the instrument and convert the digital numbers to radiance, a warm and a cold black body are measured. The µFTIR software calibrates the instrument when two blackbody measurements are taken using the external blackbody which can be put onto the fore optics.
In order to calculate emissivity, two additional parameters are needed. The first parameter is the temperature of the sample, to be measured with a thermometer. This is necessary to use the right (corresponding) Planck curve. Alternatively the maximum emissivity of the sample can be estimated based on the software. This information is used to perform a curve fit, to find the right Planck curve (and corresponding temperature of the sample).
The second parameter that is used when calculating the emissivity is the downwelling radiance. This is the spectral radiance incident on the sample from the atmosphere (Hook & Kahle, 1996). The down welling radiance is measured using a diffuse gold plate standard. The emissivity of this plate is almost zero. Therefore all radiance that is measured when pointing at the gold standard is down welling radiance. This amount is subtracted from the radiance measured of the sample when calculating emissivity.

2.2. Measurements

The µFTIR spectrometer was used to measure a set of well known minerals. In this paper measurements of quarts and nephrite are presented. In figure 2 the measured minerals are shown.
The field measurements took place at the Federal Institute for Geosciences and Natural Resources (BGR) in Hannover. First the instrument was calibrated with measurements of cold and warm black bodies. The cold black body was set at a temperature of 10° C, the warm black body at 30° C. Next measurements of the down welling radiance and of the samples themselves were taken. Each sample was measured with 20 co-adds, taking differences of the surfaces and its individual geometry into account. Simultaneously, air temperature and temperatures of the samples were measured with a contact-thermometer.
The spectra were pre-processed using the µFTIR-software to calculate the emissivity, including a Planck curve fit. For this fitting algorithm the same settings have been used for all the samples.

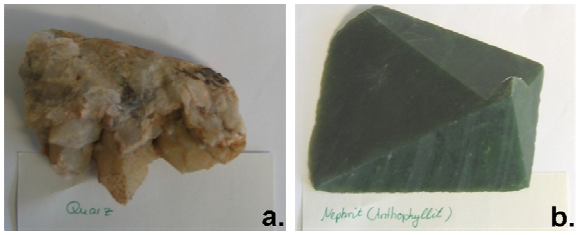

Figure 2: Two of the measured minerals: Quarts (a) and Nephrite (b)

3. RESULTS

First, different options to find the best Planck curve for the emissivity calculation were tested. In figure 3 it can be seen that both, the Planck curve corresponding to the measured temperature and the Planck curve derived by the automatic fit of the µFTIR software, do not fit perfectly. Empirical fitting of the Planck curve suggests that a sample temperature of 16° C fits best to the measured radiance. This is a difference of 5 degrees with the measured temperature of the sample.

A second experiment focused on the different surfaces of the minerals. As can be seen on the photos in figure 2, the minerals have a different surface roughness at different sides. Measurements where made of both rough or dim sides and the cut or crystal side for comparison. An example of the measured spectra is shown in figure 4. The rough and dim sides of the minerals have a higher emissivity than the crystal and cut sides. For nephrite the difference is even 50% within the adsorption feature.

The third experiment focused on the influence of the angle between sun and sensor. Emissivity spectra of quarts and nephrite under different angles are shown in figure 5. Both minerals had an inclined surface, which was once turned towards the sun and once turned away. The difference in emissivity is not as large as with the different surface types. But within the adsorption features the difference can still be up to 20 %.

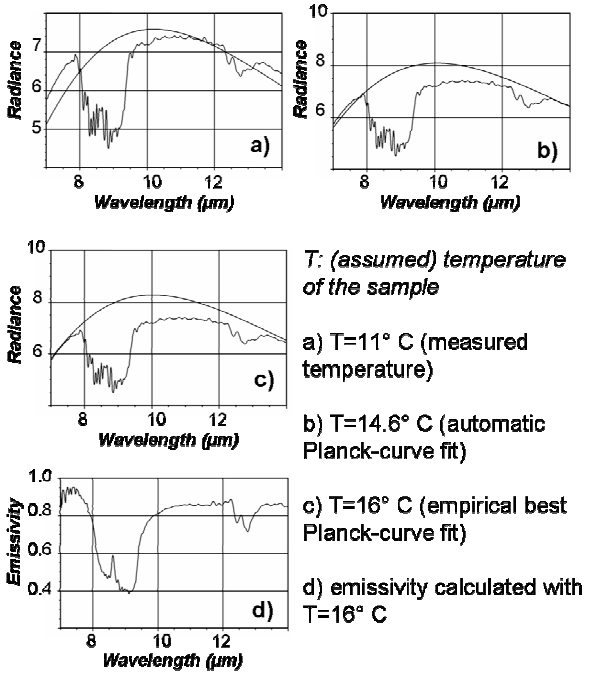

Figure 3: Radiance of quartz with Planck curves at different temperatures

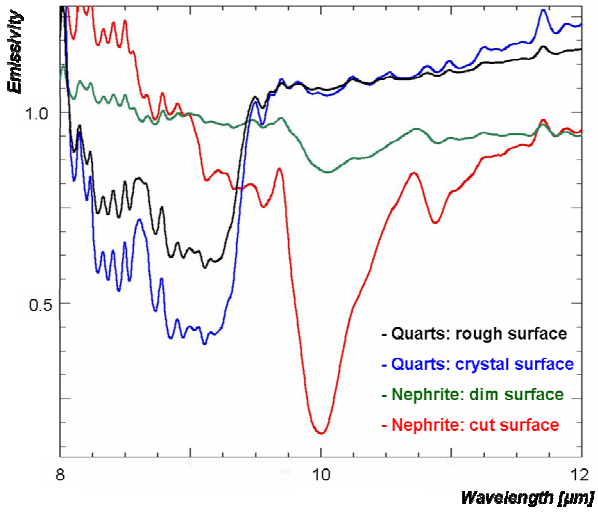

Figure 4: Emissivity of quarts and nephrite with different surfaces

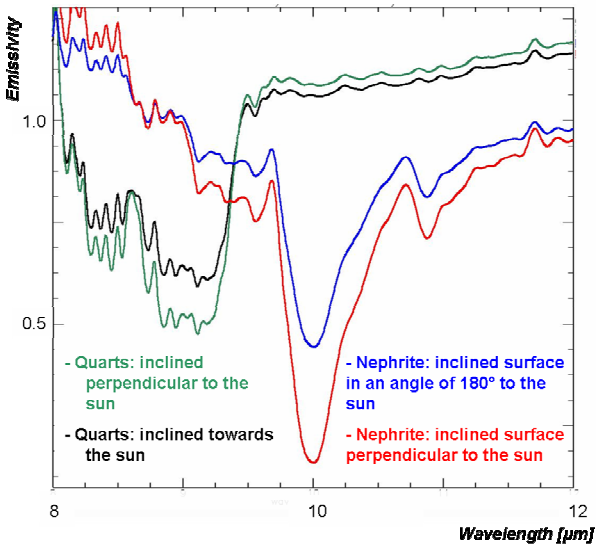

Figure 5: Emissivity of quarts and nephrite measured under different Sun-sensor angles

4. DISCUSSION

4.1 Temperature emissivity separation

The radiance curve is dived by the Planck curve to calculate the emissivity. This means also that the calculated emissivity values vary if the temperature used for the computation of the Planck curve varies. This problem of temperature emisivity separation (TES) has concerned many researchers and many solutions have been suggested (e.g. Kahle and Alley, 1992 or Kanani *et al.* 2007).

Figure 3 shows that both, the measured temperature and the Planck curve fitting included

in the µFTIR-software, do not lead to the best possible result. This indicates that the temperature of the sample should remain as stable as possible and should be measured with high accuracy. Alternatively the Planck curve fitting could be improved, for example by using an iterative approach.

4.1 Surface texture and roughness

The investigations here are based on solid samples. Different grain sizes and the corresponding effects have not been considered yet. Surface composition, texture and roughness of the target mineral influence the measurement results directly, as was shown in figure 4, although the properties of the surface are often just some micrometers to millimeters thick. Minerals with polished surface show different results in comparison to the same mineral with harsh surface properties. This is due to strong "blackbody" aspect of surface holes. In addition, a specular surface might reflect the incoming energy into the optic the sensor additionally. Similar effects based both on sample geometry and surface textures have been reported in literature (e.g. Balick *et al.* 2009). However a comprehensive solution on how to deal with the spectral variation within samples is not available at present.

4.2 Sample geometry

In figure 5 it is shown that the sample geometry influences the emissivity. A possible reason for this is that the emitting surface area of an inclined surface is comparable smaller than a surface completely exposed to the measurement device.

5. CONCLUSION AND OUTLOOK

In this paper it has been shown that there are several aspects that influence emissivity spectra measured with a field spectrometer. The influence of sample temperature, respectively Planck curve selection, surface roughness and sample geometry have been shown. When taking measurements with a thermal spectrometer, one should be aware of those influences.
Next steps will include an improvement of the algorithm for Planck curve fitting implemented in the µFTIR software by a more flexible approach based on a simplex algorithm. With this the emissivity calculation can be improved, also with in-accurate temperature information of the sample.
For future (and quantitative) measurements in comparison with lab measurements the difference between direct hemispherical and biconical hemispherical reflectance (with respect to volume scattering) has to be considered as well.
The investigations aim to describe the error budget caused by inadequate measurement procedures. After further research, the experiences will be summarized in a manual for use at DLR in a field guide on setting-up a reliable spectral library for future use of thermal hyperspectral imagery.

REFERENCES

Balick, L., A. Gillespie, A. French, I. Danilina, J.-P. Allard & A. Mushkin, 2009. Longwave Thermal Infrared Spectral Variability in Indvidual Rocks. *IEEE Geoscience and Remote Sensing Letters*, 6, pp. 52-5.

Hook, S. J. & A.B. Kahle, 1996. The Micro Fourier Transform Interferometer - A new field spectrometer for acquisition of infrared data of natural surfaces. *Remote Sensing of Environment*, 56, pp.172-181.

Kahle, A. & R. Alley, 1992. Separation Of Temperature And Emittance In Remotely Sensed Radiance Measurements. *Remote Sensing of Environment*, 42, pp. 107-111.

Kanani, K., L. Poutier, F. Nerry & M.-P. Stoll, 2007. Directional Effects Consideration to Improve out-doors Emissivity Retrieval in the 3-13 µm Domain. *Optics Express*, 15, pp.12464-12482.

Korb, A.R., P. Dybwad, W. Wadsworth and J.W. Salisbury, 1996. Portable Fourier transform infrared spectroradiometer for field measurements of radiance and emissivity. *Applied Optics*, 35, pp1679-1692.

Milton, J.E., Schaepman, M.E., Anderson, K., Kneubühler, M., Fox, N., 2007. Progress in field spectroscopy. *Remote Sensing of Environment* (in press).

Salisbury, J. W. & D.M. D'Aria, 1992. Emissivity of terrestrial materials in the 8-14 µm atmospheric window. *Remote Sensing of Environment*, 42, pp. 83-106.

ACKNOWLEDGEMENTS

The authors gratefully thank Dr. U. Schwarz-Schampera (BGR) who makes the different samples from BGRs' mineral library available. Also thanks to Dr. E. Lindemeir and C. Koehler from the Remote Sensing Technology Institute (IMF) for fundamental advices related to quality aspects of the instrument.